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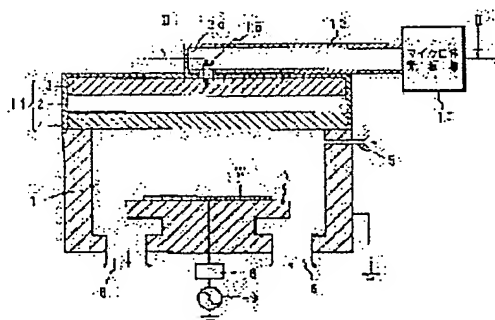
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## (54) PLASMA TREATMENT EQUIPMENT AND PLASMA TREATMENT METHOD

(57)Abstract:

PROBLEM TO BE SOLVED: To make transmission of microwaves uniformize and miniaturized a plasma treatment equipment.

SOLUTION: A microwave introducing part 11 in which a microwave introducing window 4 and a dielectric line 13 are set on the opposite to each other while keeping an air gap 2 between them is installed in the upper side of a cylindrical reaction chamber 1. A waveguide 12 is installed in the upper face of the microwave introducing chamber 11 in parallel to the dielectric line 13 and connected with the upper face through an antenna part 15. The antenna part 15 is positioned at a position parted from a reflecting end 12e of the waveguide 12 by the length equal to one fourth of the microwave length in the microwave tube while penetrating the waveguide 12 and the lower side of the waveguide 12 and the center part of the dielectric line 13 installed while sandwiching a metal plate between the waveguide and the dielectric line are connected through the antenna part 15.



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## CLAIMS

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[Claim(s)]

[Claim 1] A microwave oscillator and the waveguide which transmits the microwave from this microwave oscillator, The dielectric wire way combined with this waveguide in RF, and the microwave installation aperture by which opposite arrangement was carried out on this dielectric wire way, In plasma treatment equipment equipped with the reaction chamber the plasma is made to produce by the microwave introduced from this microwave installation aperture said dielectric wire way So that it may have allotted the direction of a track to the direction of a tube axis of said waveguide, and parallel and installation of the microwave from said waveguide to said dielectric wire way may be made in the direction at which it crosses in said direction of a tube axis, and the direction of a track Plasma treatment equipment characterized by having the antenna section for combining said waveguide and said dielectric wire way.

[Claim 2] Plasma treatment equipment according to claim 1 in said waveguide which has inserted in the dielectric near [ said ] the antenna section at least.

[Claim 3] Said antenna section is plasma treatment equipment according to claim 1 or 2 formed in the location which only distance L isolated substantially from the edge of a side which consists of conducting bars and is different from the microwave installation edge to said waveguide.

However, for  $L = (4 + n \cdot \lambda / 2) \cdot \lambda$ , integer  $n \geq 0$ ,  $\lambda$  is the guide wave length [claim 4] of microwave. Said antenna section is plasma treatment equipment according to claim 1 or 2 formed in the location which only distance L isolated substantially from the edge of a side which consists of slits a dielectric wire way is made to \*\*\*\* in said waveguide, and is different from the microwave installation edge to said waveguide.

However, for  $L = n \cdot \lambda / 2$ , integer  $n \geq 1$ ,  $\lambda$  is the guide wave length [claim 5] of microwave. Plasma treatment equipment [ equipped with the means made to expand and contract the gap of said dielectric wire way and said microwave installation aperture ] according to claim 1 or 2.

[Claim 6] Said dielectric wire way is plasma treatment equipment according to claim 1 or 2 with the larger dimension of said direction of a track than the dimension of said reaction chamber parallel to this.

[Claim 7] Said antenna section is plasma treatment equipment according to claim 1 or 2 formed in the abbreviation center section of the parallel side with said waveguide of said dielectric wire way.

[Claim 8] The thickness dimension is large in the center section of said parallel side, and said dielectric wire way is plasma treatment equipment [ small at a periphery ] according to claim 7.

[Claim 9] The thickness dimension is large in the center section of the parallel side with said dielectric wire way, and said microwave installation aperture is plasma treatment equipment [ small at a periphery ] according to claim 7.

[Claim 10] They are claims 7 and 8 in which said reaction chamber has the shape of a cylindrical shape, and said dielectric wire way and said microwave installation aperture have the shape of a disk type, or plasma treatment equipment given in either of 9.

[Claim 11] The process in which are the plasma treatment approach using plasma treatment

equipment according to claim 5, and the gap of said dielectric wire way and said microwave installation aperture is set as predetermined die length using said expanding-and-contracting means, The process which exhausts the inside of said reaction chamber and supplies reactant gas in said reaction chamber, The plasma treatment approach characterized by having the process which microwave is introduced into said waveguide and spread in said reaction chamber, and the process in which use said expanding-and-contracting means after the plasma occurs in said reaction chamber by said microwave, and said gap is expanded.

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DETAILED DESCRIPTION

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## [Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the plasma treatment equipment and the plasma treatment approach of making a semiconductor device substrate, the glass substrate for liquid crystal displays, etc. produce the plasma especially by installation of microwave about the equipment and the approach of processing etching, ashing, or CVD using the plasma.

[0002]

[Description of the Prior Art] The plasma which gives energy and is produced from the exterior in reactant gas is widely used in manufacture processes, such as LSI and LCD. Especially, in the dry etching process, use of the plasma serves as an indispensable basic technique. The case where 2.45GHz microwave is used, and 13.56MHz RF (Radio Frequency) may be used for the excitation means for making the plasma generate generally. The former does not need an electrode for plasma generating, but has the advantage that the contamination from an electrode can be prevented while the plasma of high density is acquired compared with the latter. However, if it was in the plasma treatment equipment using microwave, it was difficult to have made the plasma generate so that plasma field area might be made large and a consistency might become homogeneity, and it was not suitable to process the semi-conductor substrate of the diameter of macrostomia, the glass substrate for LCD, etc.

[0003] In order to solve this, the applicant for this patent has proposed to homogeneity the plasma treatment equipment which can generate the microwave plasma in JP,62-5600,A, JP,62-99481,A, etc. to the field of a large area. The microwave introduced from the waveguide which connected the microwave oscillator spreads a dielectric wire way, and these plasma treatment equipments have the composition that microwave is introduced into the dielectric wire way bottom in a reaction chamber through the microwave installation aperture by which opposite arrangement was carried out by having predetermined spacing. When microwave spreads from a microwave installation aperture, it becomes possible to make the plasma of a homogeneity consistency produce in a reaction chamber. Moreover, plasma treatment equipment is proposed in order to acquire the same effectiveness also in JP,8-111297,A, and this equipment is not equipped with a dielectric wire way, but it is constituted by the microwave introduced into the direct microwave installation aperture from the waveguide so that electric field may be supplied in a reaction chamber. However, since this equipment is a configuration which introduces microwave from a direct microwave installation aperture to a reaction chamber, its association with microwave and the plasma to generate is strong, and it has the problem that control of the plasma is difficult.

[0004] Drawing 13 is drawing of longitudinal section having shown the structure of the plasma treatment equipment of JP,62-5600,A and JP,62-99481,A which were proposed by the applicant for this patent, and the same type, and drawing 14 is the top view. Drawing 13 shows the cross section seen from the XI-XI line shown in drawing 14. As shown in drawing 13, plasma treatment equipment is equipped with the microwave oscillator 10 connected to the microwave installation side of the waveguide 12 connected to the microwave installation edge of the microwave induction room 11 and this microwave induction room allotted to this reaction

chamber [ which has the shape of a cylindrical shape / made from aluminum ] 1, and reaction chamber 1 bottom, and this waveguide 12, and the sample base 7 arranged in the reaction chamber 1, and is constituted. The dielectric wire way 3 and the microwave installation aperture 4 which have a gap and were allotted in parallel, and its top face and peripheral face are constituted from a wrap metal wall, and the microwave induction room 11 makes a reaction chamber 1 face the inferior surface of tongue of the microwave installation aperture 4, it maintains an airtight condition and is connected.

[0005] The microwave oscillator 10 contains the tuner for taking adjustment of microwave, and is connected to the end side of the metal waveguide 12. The dielectric wire way 3 made of a fluororesin is connected with the other end of a waveguide 12. As shown in drawing 14, plane view has the plate configuration of an abbreviation pentagon in order to raise the transmission efficiency of microwave and to make homogeneity spread the inside of a dielectric wire way, and the dielectric wire way 3 has taper section 3a to which width of face narrows in a waveguide 12 side. The dielectric wire way 3 is allotted to an abbreviation horizontal, and the point of taper section 3a is inserted in a waveguide 12, and it is being fixed. Predetermined spacing (air gap 2) is isolated to the dielectric wire way 3 down side, and the microwave installation aperture 4 is allotted to abbreviation parallel. The microwave installation aperture 4 is formed with a quartz ( $\text{SiO}_2$ ), an alumina (aluminum  $2\text{O}_3$ ), or a dielectric like aluminum nitride (AlN), and has the shape of a disk type.

[0006] In the reaction chamber 1, the sample base 7 is arranged under the microwave installation aperture 4, a sample like for example, a semi-conductor substrate is laid on the sample base 7, and plasma treatment is carried out. RF generator 9 is connected to the sample base 7 through the matching box 8. Moreover, the inlet 5 for introducing reactant gas into the side attachment wall of a reaction chamber 1 is formed, and the exhaust port 6 for carrying out evacuation of the inside of a reaction chamber 1 to a lower wall is formed. The exhauster which is not illustrated is connected to the exhaust port 6.

[0007] Thus, when performing etching processing to the front face of the semi-conductor substrate W using the constituted microwave plasma treatment equipment, reactant gas is introduced after adjusting the inside of a reaction chamber 1 to a desired pressure.

Subsequently, microwave is oscillated from a microwave oscillator 10 and it introduces into the dielectric wire way 3 through a waveguide 12. At this time, microwave spreads in homogeneity in the dielectric wire way 3 by spreading taper section 3a. And the inside of the dielectric wire way 3 is spread in the direction of a track, it is reflected at the edge covered with the metal wall, and microwave forms a standing wave in the dielectric wire way 3. Thus, while microwave spreads the dielectric wire way 3 in the direction of a track, the dielectric wire way 3 leaks caudad, electric field are formed, and this leakage electric field penetrate an air gap 2 and the microwave installation aperture 4, and are introduced in a reaction chamber 1. That is, microwave spreads in a reaction chamber 1. The plasma is generated in a reaction chamber 1 by this, and the front face of the semi-conductor substrate W is etched by the plasma.

[0008]

[Problem(s) to be Solved by the Invention] In the above conventional plasma treatment equipments, the direction of a track of a waveguide 12 and the direction of a tube axis of the dielectric wire way 3 are connected in the mode which stands in a row in this height. Therefore, a microwave oscillator 10, a waveguide 12, and taper section 3a of the dielectric wire way 3 became the structure projected to the periphery side of a reaction chamber 1, and there was a problem for which a horizontally big tooth space is [ sake / for this lobe ] needed. Especially taper section 3a was prepared in order to originate in the difference of a dimension with a waveguide 12 and the dielectric wire way 3 and to take adjustment of microwave, and in order to make homogeneity spread microwave in a reaction chamber 1, there was a problem that die length could not be shortened simply.

[0009] Moreover, as mentioned above, the dielectric wire way 3 has rectangle tabular to a reaction chamber 1 having the shape of a cylindrical shape. When processing in the sample of the diameter of macrostomia, the reaction chamber 1 of big size was used, but when microwave was introduced in the reaction chamber 1 of a major diameter, there was a problem that there

was a possibility that it may be hard coming to spread microwave to homogeneity by the difference among the configurations of a reaction chamber 1 and the dielectric wire way 3 in the direction of a path, and equalization of the plasma in a reaction chamber 1 may become difficult by this.

[0010] This invention aims at offering the plasma treatment equipment miniaturized by omitting the field for adjustment of the microwave resulting from a difference of the dimension of each part of both by being made in view of this situation, allotting a waveguide and a dielectric wire way in parallel, and joining together so that microwave may be introduced through the antenna section from the direction at which it crosses in the direction of a track.

[0011] Moreover, it aims at offering the plasma treatment equipment which makes homogeneity produce the plasma in the reaction chamber of the diameter of macrostomia by forming a dielectric wire way and a reaction chamber in the shape of isomorphism by plane view.

[0012] Furthermore, according to the condition of the plasma in a reaction chamber, it aims at offering the plasma treatment equipment and the plasma treatment approach of lighting the plasma easily and making homogeneity generate the plasma by carrying out adjustable setting of the gap dimension between a dielectric wire way and a microwave installation aperture.

[0013]

[Means for Solving the Problem] The waveguide with which the plasma treatment equipment concerning the 1st invention transmits the microwave from a microwave oscillator and this microwave oscillator, The dielectric wire way combined with this waveguide in RF, and the microwave installation aperture by which opposite arrangement was carried out on this dielectric wire way, In plasma treatment equipment equipped with the reaction chamber the plasma is made to produce by the microwave introduced from this microwave installation aperture said dielectric wire way It is characterized by having the antenna section for combining said waveguide and said dielectric wire way so that it may have allotted the direction of a track to the direction of a tube axis of said waveguide, and parallel and installation of the microwave from said waveguide to said dielectric wire way may be made in the direction at which it crosses in said direction of a tube axis, and the direction of a track.

[0014] If it is in the 1st invention, the microwave which spread the waveguide is introduced from the direction at which a dielectric wire way is crossed in the direction of a track through the antenna section. And microwave spreads a dielectric wire way in the direction of a track, and is spread in the direction which goes to a microwave installation aperture by the propagating mode by surface wave electric field from the inferior surface of tongue of a dielectric wire way. A waveguide and a dielectric wire way are parallel, and since it is located in the direction at which it crosses in the direction of a track, the wire extension to the die-length direction of a waveguide becomes short. Since association with a waveguide and a dielectric wire way was especially made into antenna structure, the field for adjustment resulting from the difference of a dimension with a waveguide and a dielectric wire way is not needed, but the miniaturization of equipment is attained.

[0015] The plasma treatment equipment concerning the 2nd invention is characterized by the thing in said waveguide for which the dielectric is inserted in near [ said ] the antenna section at least in the 1st invention.

[0016] If it is in the 2nd invention, the potential around the antenna section falls by inserting in a dielectric in a waveguide. Thereby, when high power is supplied to equipment, the abnormality discharge produced frequently can be prevented and microwave power can be supplied to stability. Moreover, a characteristic impedance falls by inserting in a dielectric in a waveguide. When this prepares the antenna section in the location of the antinode of the current standing wave formed in a waveguide wall surface to a slit, the potential difference between the long sides of slit opening becomes large rather than the case where the dielectric is not inserted in in a waveguide. Therefore, the high density plasma is effectively generated by supply of the same power.

[0017] The plasma treatment equipment concerning the 3rd invention is characterized by having prepared said antenna section in the location which only distance L isolated substantially from the edge of a side which consists of conducting bars and is different from the microwave

installation edge to said waveguide in the 1st invention. However, an integer,  $n \geq 0$ , and  $\lambda_{\text{dag}}$  are  $L = (4 + n \cdot \lambda_{\text{dag}}/2) \cdot \lambda_{\text{dag}}$ , and  $n$  is the guide wave length of microwave.

[0018] If it is in the 3rd invention, since the antenna section formed with the conducting bar is prepared in wavelength twice  $(4 + n \cdot \lambda_{\text{dag}}/2)$  the location of microwave, and the maximum location (location of an antinode) of the voltage standing wave in a waveguide from the microwave reflective edge of a waveguide, microwave is supplied to a dielectric wire way from a waveguide still more efficiently.

[0019] The plasma treatment equipment concerning the 4th invention is characterized by having prepared said antenna section in the location which only distance  $L$  isolated substantially from the edge of a side which consists of slits said waveguide and dielectric wire way are made to \*\*\*\*, and is different from the microwave installation edge to said waveguide in the 1st invention. However, an integer,  $n \geq 1$ , and  $\lambda_{\text{dag}}$  are  $L = n/2 \cdot \lambda_{\text{dag}}$ , and  $n$  is the guide wave length of microwave.

[0020] If it is in the 4th invention, since the antenna section formed to the slit is prepared in wavelength twice  $(n/2)$  the location of microwave, and the location of the antinode of the current standing wave of a waveguide wall surface from the reflective edge of a waveguide, microwave is supplied to a dielectric wire way still more efficiently through a slit from a waveguide.

[0021] The plasma treatment equipment concerning the 5th invention is characterized by having the means made to expand and contract the gap of said dielectric wire way and said microwave installation aperture in the 1st or 2nd invention. Moreover, the plasma treatment approach concerning the 11th invention The process in which are the plasma treatment approach using the plasma treatment equipment of the 5th invention, and the gap of said dielectric wire way and said microwave installation aperture is set as predetermined die length using said expanding-and-contracting means, The process which exhausts the inside of said reaction chamber and supplies reactant gas in said reaction chamber, Microwave is introduced into said waveguide and it is characterized by having the process spread by said microwave in said reaction chamber, and the process in which use said expanding-and-contracting means after the plasma occurs in said reaction chamber by said microwave, and said gap is expanded.

[0022] If it is in the 5th invention and the 11th invention, it narrows, propagation of the microwave to a reaction chamber is made powerful until the plasma generates the gap between a dielectric wire way and a microwave installation aperture, and ignition of the plasma is made easy. After generating the plasma, association with the microwave which extends a gap dimension and spreads a dielectric wire way, and the plasma in a reaction chamber is weakened, microwave spreads in homogeneity on a dielectric wire way, and the surface wave electric field formed in the inferior surface of tongue can be made into homogeneity. Thereby, the uniform plasma occurs in the direction of a path which spread also in the periphery, without concentrating on the center section of the reaction chamber.

[0023] The plasma treatment equipment concerning the 6th invention is characterized by said dielectric wire way having the dimension of said direction of a track larger than the dimension of said reaction chamber parallel to this in the 1st or 2nd invention.

[0024] If it is in the 6th invention, the dimension of the direction of a track of a dielectric wire way is larger than the dimension of a reaction chamber parallel to this. Usually, the reinforcement of the surface wave electric field of the microwave to spread shows distribution with a low periphery with the high core of a dielectric wire way. Therefore, since only the field where the field strength of the surface wave electric field of microwave is high can be alternatively used for plasma generating, equalization of the plasma in a reaction chamber and improvement in the speed of the processing speed of a sample are attained.

[0025] Said antenna section is characterized by having formed the plasma treatment equipment concerning the 7th invention in the abbreviation center section of the parallel side with said waveguide of said dielectric wire way in the 1st or 2nd invention.

[0026] If it is in the 7th invention, microwave is introduced from the abbreviation center section of the dielectric wire way, and spreads to a periphery. Electric-field distribution is uniform and the circular TE<sub>11</sub> mode, the TE<sub>01</sub> mode, etc. which are the propagating mode of extremely



stable microwave are the mode in which the field strength of a center section is powerful. By introducing the microwave of such propagating modes from the center of a dielectric wire way, electric-field distribution is uniform and the microwave in extremely stable surface wave electric-field mode spreads in a reaction chamber.

[0027] The plasma treatment equipment concerning the 8th invention is characterized by its the thickness dimension of said dielectric wire way being large in the center section of said parallel side, and being small at a periphery in the 7th invention. Moreover, the plasma treatment equipment concerning the 9th invention is characterized by the thickness dimension of said microwave installation aperture being large in the center section of the parallel side with said dielectric wire way, and being small at a periphery in the 7th invention.

[0028] If it is in the 8th invention and the 9th invention, the thickness of a center section of a dielectric wire way and a microwave installation aperture is thick, and it has formed in a configuration to which a periphery becomes thin. If a reaction chamber becomes a diameter of macrostomia with diameter-ization of macrostomia of a sample, microwave is spread by the spherical wave, the core of velocity of propagation (phase velocity) will be quick, and a periphery will become late. A phase may reverse the intensity distribution of the microwave standing wave in which the microwave reflected by the interface of a microwave installation aperture and the plasma or sample \*\*\*\* in a reaction chamber and the microwave introduced from a microwave installation aperture are formed by interfering by this by the core and periphery in the same height by the principle of superposition. At this time, it turns out experientially that the homogeneity of the plasma is bad. Therefore, by being thick and making thin thickness of a dielectric wire way and a microwave installation aperture by the periphery in a core, the effective distance (optical path) of microwave is compensated, propagation of microwave is maintained in the shape of a plane wave, and the plasma in a reaction chamber is equalized.

[0029] It is characterized by, as for said reaction chamber, for the plasma treatment equipment concerning the 10th invention having the shape of a cylindrical shape in the 7th, 8, or 9 invention, and said dielectric wire way and said microwave installation aperture having the shape of a disk type.

[0030] If it is in the 10th invention, a reaction chamber has the shape of a cylindrical shape, and has formed the dielectric wire way and the microwave installation aperture in the shape of a disk type. Therefore, by introducing microwave from the abbreviation center section of the dielectric wire way, it can consider that a dielectric wire way, a microwave installation aperture, and a reaction chamber are also kinds of a waveguide, and microwave is spread to the axial symmetry of a travelling direction. Consequently, the microwave in surface wave electric-field mode is spread to homogeneity into a reaction chamber.

[0031]

[Embodiment of the Invention] Hereafter, this invention is concretely explained based on the drawing in which the gestalt of the operation is shown.

Gestalt 1. drawing 1 of operation is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 1 of operation of this invention, and drawing 2 shows the cross-sectional view seen from the II-II line of drawing 1. As shown in drawing 1, it be allotted in parallel with the top face of the microwave induction room 11 allotted to this reaction chamber [ of the product made from aluminum for example, ] 1, and reaction chamber 1 bottom to which plasma treatment equipment have the shape of a cylindrical shape, and this microwave induction room 11, and it have the microwave oscillator 10 connected to the end side of the waveguide 12 connected through the antenna section 15 mentioned later, and this waveguide 12, and the sample base 7 arranged in the reaction chamber 1, and be constituted. The microwave induction room 11 consists of wrap metal walls in the dielectric wire way 13 and the microwave installation aperture 4 by which have a predetermined gap (air gap 2) and opposite arrangement was carried out in parallel with a top and the bottom and which have the shape of a disk type, and the periphery section of these and the top face of the dielectric wire way 13. The closure of the reaction chamber 1 is airtightly carried out by the microwave installation aperture 4.

[0032] The microwave oscillator 10 contains the tuner for taking adjustment of microwave, and is

connected to the end side of the waveguide 12 arranged on the abbreviation horizontal. A waveguide 12 is metal, an other end side is blockaded and the microwave to spread reflects it at this edge (reflective edge 12e). Have a shaft center in the location which separated only quadrant microwave wavelength ( $\lambda/4$  and  $\lambda$  are the wavelength in the microwave tube) from reflective edge 12e, and the antenna section 15 is installed through the base of a waveguide 12. It is installed through a part for the abbreviation core of the top face of the dielectric wire way 13 where a part for the point of the antenna section 15 was furthermore allotted through the metal wall with the waveguide 12 down side, and the waveguide 12 and the dielectric wire way 13 are connected by the antenna section 15. In addition, although the arrangement location of the antenna section 15 is not restricted only to the location which separated only  $\lambda/4$  from reflective edge 12e of a waveguide 12, it is desirable to have prepared in the location from which only  $x(4+n[1/2])\lambda$  (an integer,  $n \geq 0$ , and  $\lambda$  are the wavelength in the microwave tube for  $n$ ) was separated.

[0033] The dielectric wire way 13 is a product made of a fluororesin like Teflon (trademark), as shown in drawing 2, it has the shape of a disk type, and it has allotted the direction of a track in parallel with the abbreviation level of a tube axis, i.e., the direction of a waveguide 12. As mentioned above, said antenna section 15 is implanted in a part for the abbreviation core of the top face of the dielectric wire way 13. Drawing 3 is the sectional view having expanded and shown a part for the bond part of the waveguide 12 connected by the antenna section 15 and the dielectric wire way 13. The antenna section 15 consists of metal conducting bar 15a like aluminum, and annular insulator 15b which consists of an insulator like the ceramic of a quartz system or an alumina system. The hole for the pushes in of the antenna section 15 is formed in the base and metal wall of a waveguide 12, and the hole for immobilization of conducting bar 15a is formed in the top face of the dielectric wire way 13. As shown in drawing 3, fitting of the insulator 15b is carried out to the peripheral face of conducting bar 15a in the center of the die-length direction abbreviation, insulator 15b is inserted in the base of a waveguide 12, and the hole of a metal wall, the lower part of conducting bar 15a is inserted in the hole of the dielectric wire way 13, and the antenna section 15 is being fixed in the mode which made the upper part of conducting bar 15a set up within a waveguide 12.

[0034] Only predetermined spacing (air gap 2) is isolated to the dielectric wire way 13 down side, and the microwave installation aperture 4 is allotted to it in parallel with the abbreviation horizontal 13, i.e., a dielectric wire way. The microwave installation aperture 4 which has the shape of a disk type as mentioned above has thermal resistance and microwave permeability, and is formed with dielectrics, such as a quartz ( $\text{SiO}_2$ ) with small dielectric loss, an alumina (aluminum  $\text{2O}_3$ ), or aluminum nitride (AlN).

[0035] In the reaction chamber 1, the sample base 7 is caudad arranged for the microwave installation aperture 4, for example, the microwave installation aperture 4 is made to face a sample like the semi-conductor substrate W, and it lays on the sample base 7, for example, plasma treatment like etching is carried out. In order to control an etching configuration, RF generator 9 is connected to the sample base 7 through the matching box 8. The inlet 5 for introducing reactant gas into the side attachment wall of a reaction chamber 1 is formed, and the exhaust port 6 for carrying out evacuation of the inside of a reaction chamber 1 to a lower wall is formed. The exhaustor which is not illustrated is connected to the exhaust port 6. Moreover, the solvent flowing path which is not illustrated is established in the perimeter of a reaction chamber 1, and adjustment of the temperature in a reaction chamber 1 is attained.

[0036] Such plasma treatment equipment of a configuration has allotted mutually the direction of a tube axis of a waveguide 12, and the direction of a track of the dielectric wire way 13 in parallel, and the dielectric wire way 13 and the waveguide 12 are connected so that it may be located up and down. For the plasma treatment equipment mentioned above, the bore of a reaction chamber 1 is a diameter. 340mm and the dielectric wire way 13 are a diameter. 440mm, the thickness of 20mm, and the microwave installation aperture 4 are a diameter. 440mm, the thickness of 20mm, and the antenna section 15 are the diameter of 15mm, Die length of 30mm, Fixed positions are  $\lambda/4 = 40\text{mm}$  from a reflective edge. This equipment is used and it is a diameter. It is possible to process an about 200mm substrate.

[0037] When performing etching processing to the semi-conductor substrate W using the plasma treatment equipment like \*\*\*\*, the inside of a reaction chamber 1 is adjusted to a predetermined pressure, and it is C four F8 from the reactant gas inlet 5. And O2 Reactant gas [ like ] is supplied in a reaction chamber 1. Subsequently, microwave is introduced into a waveguide 12 with a microwave oscillator 10. The microwave which spread the inside of a waveguide 12 is introduced from the core of the dielectric wire way 13 through conducting bar 15a of the antenna section 15. Since the antenna section 15 is formed in the location where only  $x\lambda_{\text{mdag}}$  (an integer,  $n \geq 0$ , and  $\lambda_{\text{mdag}}$  are the wavelength in the microwave tube for  $n$ ) separated that medial axis from the reflective edge of a waveguide  $(4+n [ 1/ ]/2)$ , i.e., the location of the antinode of the voltage standing wave in a waveguide, at this time, microwave is efficiently introduced into a dielectric wire way from a waveguide.

[0038] The propagating mode determined in the configuration of the dielectric wire way 13 from the rectangle TE 10 whose microwave introduced into the dielectric wire way 13 is the basic propagating mode in a waveguide 12, for example, the circular TE11 mode, is changed into the mixed mode of circular TE11 and circular TE01 etc. only for the circular TE01 mode. It is spread the microwave in these circular modes decreasing microwave exponentially in the direction which goes to the microwave installation aperture 4 by the propagating mode by the electric field which spread the inside of the dielectric wire way 13 from a core in the direction of a track to a periphery at a radial, and are called a surface wave from the inferior surface of tongue of the dielectric wire way 13. The microwave by the spread surface wave electric-field mode penetrates an air gap 2 and the microwave installation aperture 4, and is supplied in a reaction chamber 1. In a reaction chamber 1, the plasma arises by surface wave electric field, reactant gas is activated by ion, the radical, etc. with the energy of this plasma, it acts on the semi-conductor substrate W with which ion or a radical was laid on the sample base 7, and etching processing is performed.

[0039] Thus, since the plasma treatment equipment of the gestalt 1 of operation has the comparable dimension of microwave induction (antenna section 15) at the waveguide 12 and dielectric wire way 13 side, it becomes unnecessary [ a field like the taper section for adjustment of the microwave resulting from a difference of a dimension ]. That is, the plasma treatment equipment of the gestalt 1 of operation pulls out the high potential formed by the waveguide 12 side by microwave induction (antenna section 15), and supplies high potential to the dielectric wire way 13 side as it is. In the dielectric wire way 13, electric-field distribution is formed in the mode in which electric field are decided according to the configuration of breadth and the dielectric wire way 13 from the antenna section 15. That is, predetermined electric-field mode can be made to form in the dielectric wire way 13 by \*\*\*\*\* of the antenna section 15. Consequently, in order to make predetermined electric-field mode form (i.e., in order to adjust microwave), a field like the taper section which was the need conventionally can be made unnecessary. Moreover, since the waveguide 12 and the dielectric wire way 13 are arranged up and down, the wire extension to the direction of a tube axis of a waveguide 12 becomes short, and the miniaturization of equipment is attained.

[0040] Moreover, the microwave in the surface wave electric-field mode which spread the central field of the dielectric wire way 13 spreads in a reaction chamber 1 by one with the larger (100mm size) diameter dimension of the dielectric wire way 13 than the diameter dimension of a reaction chamber 1. The field strength (for example, the circular TE11 mode or the circular TE01 mode) of microwave has a high core, and since a periphery has low crest type distribution and only the central field where the field strength of microwave is high can be alternatively used for plasma generating, the plasma in a reaction chamber is equalized. Moreover, the processing speed of a sample is accelerated.

[0041] Furthermore, a reaction chamber 1 is a cylindrical shape, and since the dielectric wire way 13 and the microwave installation aperture 4 have the shape of a disk type, when the microwave in the circular TE01 mode spreads, it can consider that the dielectric wire way 13, the microwave installation aperture 4, and a reaction chamber 1 are kinds of a waveguide, and microwave can spread to the medial-axis symmetry and can spread the microwave in surface wave electric-field mode to homogeneity into a reaction chamber 1. Moreover, when the path in

the dielectric wire way 14, the microwave installation aperture 4, and a reaction chamber 1 is set up so that a characteristic impedance may not change suddenly, a power reflection factor can always be stopped low in a microwave (2.45GHz) band, and power efficiency improves further.

[0042] Gestalt 2. drawing 4 of operation is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 2 of operation. As shown in drawing 4, plasma treatment equipment The shape of a cylindrical shape The top face and the periphery section of the disc-like dielectric wire way 13 and this dielectric wire way 13 by which opposite arrangement was carried out to this disc-like microwave installation aperture [ which was attached in the upper part of the reaction chamber 1 of the product made from aluminum for example, and this reaction chamber 1 which it has in the mode which closes the inside of a reaction chamber 1 ] 4, and microwave installation aperture 4 up side It is allotted in parallel with the dielectric wire way 1 with this metal rise-and-fall section 11a [ which was fixed ] and rise-and-fall section 11a up side. It has the waveguide 12 connected with the dielectric wire way 13 through the antenna section 15 mentioned later, the microwave oscillator 10 connected to the end side of this waveguide, and the sample base 7 arranged in the reaction chamber 1, and is constituted.

[0043] Rise-and-fall section 11a has connected the rise-and-fall driving gear 16, and both the dielectric wire way 13, the antenna section 15, the waveguide 12, and the microwave oscillator 10 carry out vertical migration by the drive of the rise-and-fall driving gear 16. At this time, the dielectric wire way 13 carries out vertical migration, maintaining the microwave installation aperture 4 and parallel, and adjustment of the gap dimension of an air gap 2 of it is attained. Other configurations are the same as that of the gestalt 1 of operation mentioned above, give a same sign to a part for the said division, and omit explanation.

[0044] When [ like \*\*\*\* ] performing etching processing to the semi-conductor wafer W using the plasma treatment equipment of a configuration, drive the rise-and-fall driving gear 16, rise-and-fall section 11a is made to move first, and the gap dimension of an air gap 2 is adjusted to 7mm. Subsequently, the inside of a reaction chamber 1 is adjusted to a predetermined pressure, and it is C four F8 from the reactant gas inlet 5. And O2 Reactant gas [ like ] is supplied in a reaction chamber 1. And microwave is introduced into a waveguide 12 with a microwave oscillator 10. Microwave spreads the inside of a waveguide 12 and is introduced into the dielectric wire way 13 from a core through the antenna section 15. The microwave introduced into the dielectric wire way 13 is spread from a core to a periphery, and is spread from the inferior surface of tongue of the dielectric wire way 13 by the propagating mode by surface wave electric field to coincidence in the direction which goes to the microwave installation aperture 4. The spread microwave penetrates an air gap 2 and the microwave installation aperture 4, is introduced in a reaction chamber 1, and makes the plasma produce in a reaction chamber 1.

[0045] After the plasma arises in a reaction chamber 1, rise-and-fall section 11a is moved to the bottom by the drive of the rise-and-fall driving gear 16. The gap dimension of an air gap 2 is expanded making the plasma produce in a reaction chamber 1, and the rise of rise-and-fall section 11a is suspended after expansion termination in a predetermined dimension. With the gestalt of this operation, it expands to 20mm. Plasma treatment is succeedingly performed to Sample W, and in a predetermined period, after a migration halt of rise-and-fall section 11a suspends supply of the microwave from a microwave oscillator 10, and ends etching processing. In addition, detection of plasma generating in a reaction chamber 1 is made by detecting luminescence in the case for example, of plasma generating with an optical fiber. In addition, the gap dimension of the air gap 2 until the plasma arises may be zero.

[0046] The surface wave electric field of microwave become strong, and it becomes easy to produce the plasma in a reaction chamber 1, so that the gap dimension of an air gap 2 is small. Moreover, the plasma in a reaction chamber 1 is equalized in the direction of a path, so that the gap dimension of an air gap 2 is large. Therefore, with the gestalt of this operation, the gap dimension of an air gap 2 is made small, the plasma is made easy to generate, after the plasma occurs, a gap dimension is expanded and the plasma in a reaction chamber 1 is equalized, until the plasma arises in a reaction chamber 1. A sample can be processed to homogeneity, without the plasma concentrating by this in the location directly under an antenna which is a part for

microwave induction. Moreover, after plasma generating, by making the antenna section 15 far from a plasma generating field, a power reflection factor can be made low and microwave power efficiency improves.

[0047] Gestalt 3. drawing 5 of operation is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 3 of operation. Except that the configurations of dielectric wire way 13a differ, it is the same configuration as the gestalt 1 of operation mentioned above, and a same sign is given to a part for the said division, and explanation is omitted. Dielectric wire way 13a is a truncated-cone configuration which has a taper in an inferior-surface-of-tongue side, for example, a diameter on top The diameter of 440mm and an inferior surface of tongue It is 100mm and thickness T of a center section is [ thickness t of 27mm and an outside periphery ] 20mm.

[0048] Etching processing is carried out using the plasma treatment equipment of the configuration like \*\*\*\* in the same procedure as the gestalt 1 of operation of the semi-conductor substrate W. Since the microwave of surface wave propagating mode is spread in the shape of a spherical wave from dielectric wire way 13a, the center section of velocity of propagation (phase velocity) is quick, and its periphery is late. With the gestalt of this operation, since a center section and a periphery are changed in the thickness of dielectric wire way 13a, it is long and effective distance of microwave is shortened by the periphery in the center section, propagation of microwave can be maintained in the shape of a plane wave. Thereby, microwave has equiphase in the same height within plasma treatment equipment. Therefore, as for the intensity distribution of the microwave standing wave formed when the microwave reflected in the interface of the microwave installation aperture 4 and the plasma or the microwave reflected on the sample base 7 in a reaction chamber 1, and the microwave spread from the microwave installation aperture 4 interfere, a center section and a periphery have complete set of phase in the same height by the principle of superposition. Consequently, it becomes possible to make homogeneity spread microwave in a reaction chamber 1, and the uniform plasma can be formed.

[0049] Moreover, drawing 6 is drawing of longitudinal section showing the structure of other plasma treatment equipments of the gestalt 3 of operation. Except that the configurations of microwave installation aperture 4a differ, it is the same configuration as the gestalt 1 of operation mentioned above, and a same sign is given to a part for the said division, and explanation is omitted. Microwave installation aperture 4a is a truncated-cone configuration which has a taper in a top-face side, for example, a diameter on top The diameter of 100mm and an inferior surface of tongue It is 440mm and thickness T of a center section is [ thickness t of 27mm and an outside periphery ] 20mm.

[0050] Etching processing is carried out using the plasma treatment equipment of the configuration like \*\*\*\* in the same procedure as the gestalt 1 of operation of the semi-conductor substrate W. Since microwave is introduced in the shape of a spherical wave in microwave installation aperture 4a, the velocity of propagation (phase velocity) within the microwave installation aperture 4 has a quick center section, and its periphery is late. With the gestalt of this operation, since a center section and a periphery are changed in the thickness of the microwave installation aperture 4, it is long and effective distance of microwave is shortened by the periphery in the center section, propagation of microwave can be maintained in the shape of a plane wave. Thereby, microwave has equiphase in the same height within plasma treatment equipment. Therefore, as for the intensity distribution of the microwave standing wave in a reaction chamber 1, a phase gathers by the center section and the periphery in the same height. It becomes possible to make homogeneity spread microwave in a reaction chamber 1 by this, and the uniform plasma can be formed.

[0051] If it is in the plasma treatment equipment of the gestalt 3 of operation like the above, it is effective in the equipment which the same effectiveness as the gestalt 1 of operation is acquired, and the further equalization of the plasma in a reaction chamber of is still attained, and has a reaction chamber for the diameter samples of macrostomia.

[0052] Moreover, in the equipment of the gestalten 1-3 of operation mentioned above, the microwave of the specific mode like for example, the circular TE11 mode, the circular TE01 modes, or such mixed modes can be spread by forming a dielectric wire way and a microwave

installation aperture with a predetermined path, and setting the gap as a predetermined dimension. Thereby, desired field strength distribution can be acquired in the microwave induction room 11, and desired plasma distribution can be acquired in a reaction chamber 1.

[0053] Drawing 7 is a graph which shows the field strength distribution in the dielectric wire way by the propagating mode of microwave. An axis of ordinate shows field strength and the axis of abscissa shows the location of a dielectric wire way. As shown in a graph, the highest field strength among parts for the core of a dielectric wire way is shown, and, as for the circular TE11 mode, the periphery shows low field strength. From this, when the propagating mode of microwave is the circular TE11 mode, desired field strength distribution can be formed like the gestalten 1-3 of operation mentioned above by forming the antenna section 15 in a part for the core of a dielectric wire way.

[0054] The case where gestalt 4. of operation and the propagating mode of microwave are the circular TE01 modes is explained below. As shown in drawing 7, the circular TE01 mode shows the field strength highest than the core of a dielectric wire way in the perimeter, and electric field are low again by the periphery further from the field.

[0055] Drawing 8 is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 4 of operation. Except that the number and installation location of the antenna section differ from each other, it is the same configuration as the gestalt 1 of operation mentioned above, and a same sign is given to a part for the said division, and explanation is omitted. As shown in drawing 8, the waveguide 12 and the dielectric wire way 13 are combined by the 1st and 2nd antenna sections 151,152. For the 1st antenna section 151, the shaft center is reflective edge 12e of a waveguide 12 to the distance L1. For the 2nd antenna section 151, to a location, the shaft center is reflective edge 12e of a waveguide 12 to the distance L2. It is prepared in the location and the two antenna sections 151,152 are formed in the position of symmetry to the medial axis of the dielectric wire way 13 which has the shape of a disk type. Here, it is distance  $L1 = (1/4) \text{ lambdag}$ , and is distance  $L2 = (5/4) \text{ lambdag}$ .

[0056] With the plasma treatment equipment of a configuration, the field strength distribution for the circular TE01 mode in which the field strength highest than the core of a dielectric wire way in the perimeter be show can be acquire by acquire the same effectiveness as the gestalt 1 of operation like \*\*\*\*, and having form the antenna section 151,152 in the location (L1 and L2) which separated only the equal distance from the core of the dielectric wire way 13 further. By acquiring field strength distribution of such medial-axis symmetry, microwave can be spread to homogeneity in the direction of a path.

[0057] in addition, the thing restricted to this although the gestalten 1-4 of operation mentioned above explain the case where a rod-like conductor is used as an antenna -- it is not -- for example, the tip of the dielectric wire road side of a conducting bar -- a spoke-like electrode and a conductor -- what attached a metal like a plate may be used.

[0058] The top face of gestalt 5. of operation, and a waveguide and a dielectric wire way may be established for a slit in a wrap metal wall, and microwave may be transmitted by making this into the antenna section. Drawing 9 is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 5 of operation. Moreover, drawing 10 is the cross-sectional view seen from X-X-ray of drawing 9. Except the 1st [ which connects a waveguide 12 and the dielectric wire way 13 ], 2nd, and 3rd antenna section 251,252,253, the plasma treatment equipment of the gestalt of this operation is the same as that of the configuration of the gestalt 1 of operation mentioned above, gives a same sign to a part for the said division, and omits explanation.

[0059] The waveguide 12 is attached in the top face of the dielectric wire way 13 as shown in drawing 9. The 1st, 2nd, and 3rd antenna sections 251,252,253 are formed to the slit which penetrates the base of a waveguide 12, and the metal wall on the dielectric wire way 13. For the 1st antenna section 251, at a waveguide 12 side, the core is reflective edge 12e of a waveguide 12 to the distance L1. To a location, the 2nd antenna section 252 is distance L2. To a location, the 3rd antenna section 253 is distance L3. It is prepared in the location. And in the dielectric wire way 13 side, the 2nd antenna section 252 is formed in the core in the top face of the dielectric wire way 13, and the 1st and 3rd antenna sections 251,253 are formed in the position



of symmetry to the 2nd antenna section. Here, they are distance  $L1 = (1/2) \lambda$ , distance  $L2 = \lambda$ , and distance  $L3 = (3/2) \lambda$ .

[0060] Microwave is introduced into a waveguide 12, after adjusting the inside of a reaction chamber 1 to a predetermined pressure and supplying reactant gas in a reaction chamber 1 from the reactant gas inlet 5, when performing etching processing to the semi-conductor substrate W using the plasma treatment equipment like \*\*\*\*. The microwave which spread the inside of a waveguide 12 is introduced into the dielectric wire way 13 through the slit of the 1st, 2nd, and 3rd antenna sections 251, 252, 253. Since each antenna section 251, 252, 253 is formed in the location from which only  $n/2 \lambda$  (an integer,  $n \geq 1$ , and  $\lambda$  are the wavelength in the microwave tube for  $n$ ) was separated, i.e., the location of the antinode of the current standing wave in a waveguide, from reflective edge 12e of a waveguide at this time, microwave is efficiently introduced into a dielectric wire way from a waveguide.

[0061] Since the plasma treatment equipment of the gestalt 5 of operation acquires the same effectiveness as the gestalt 1 of operation like the above and the antenna section 251, 252, 253 is further formed to the slit, simplification of cost reduction and manufacture is attained.

[0062] Gestalt 6. of operation, next the plasma treatment equipment which inserted in the dielectric in the waveguide are explained. Drawing 11 is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 6 of operation of this invention. In the waveguide 12, dielectric 12c like Teflon (trademark) is inserted in. It fills up with dielectric 12c in the direction of a tube axis from the reflective edge 12e side of a waveguide 12 to the position, and taper section 12a to which the edge by the side of a microwave oscillator 10 made upside thickness thin is formed. It has prepared in order for taper section 12a to make matching section reflection of microwave reduce, and the dimension is  $n/4 \lambda$  in the direction of a tube axis. However, an integer,  $n \geq 1$ , and  $\lambda$  of  $n$  are the wavelength in the microwave tube.

[0063] In the waveguide 12, it has a shaft center in the location which separated only quadrant microwave wavelength ( $\lambda/4$ ) from reflective edge 12e, and the antenna section 15 is installed. The antenna section 15 is a metal conducting bar, the lower limit part is fixed centering on the top face of the dielectric wire way 13, and dielectric 12c in a waveguide 12 and the dielectric wire way 13 are connected by the antenna section 15. In addition, the location of the antenna section 15 may be established in the location from which only not only a location but  $x (4+n [1/2]) \lambda$  (an integer,  $n \geq 0$ , and  $\lambda$  are the wavelength in the microwave tube for  $n$ ) which is separated from reflective edge 12e  $\lambda/4$  was separated. Other configurations and the procedure of plasma treatment are the same as that of the gestalt 1 of operation mentioned above, and omit the explanation.

[0064] By such the charge of dielectric 12c, about 15 antenna section potential becomes low as compared with the case where the dielectric is not inserted in in the waveguide 12. By calculating characteristic-impedance  $Z$  in a flat waveguide shows this. Using the flat waveguide of 96mmx27mm size, when electric-field mode is the rectangle TE<sub>10</sub> mode, characteristic-impedance  $Z$  is called for by the following formulas.

[0065]

[Equation 1]

$$\text{特性インピーダンス } Z = \frac{\sqrt{\mu_0 / (\epsilon_r \times \epsilon_0)}}{\sqrt{1 - (f_c / f)^2}}$$

但し、 $\mu_0$  : 真空中の透磁率

$\epsilon_0$  : 真空中の誘電率

$\epsilon_r$  : 比誘電率

導波管内が空気るとき  $\epsilon_r = 1$

導波管内がテフロンるとき  $\epsilon_r = 2.1$

$f$  : マイクロ波の周波数

$f_c$  : マイクロ波のカットオフ周波数

導波管内が空気るとき

$$\begin{aligned} f_c &= c / 2a \\ &= 3 \times 10^{11} / 96 / 2 \\ &= 1.56 \times 10^9 \text{ Hz} \end{aligned}$$

導波管内がテフロンるとき

$$\begin{aligned} f_c &= c / 2a \\ &= 3 \times 10^{11} / 96 / \sqrt{2.1} / 2 \\ &= 1.08 \times 10^9 \text{ Hz} \end{aligned}$$

$a$  : 導波管の管軸方向に交わる幅寸法

$c$  : 光速

である。従って導波管内が空気である場合の特性インピーダンス  $Z$  は、

$$\begin{aligned} Z &= \frac{\sqrt{4\pi \times 10^{-7} / 8.85 \times 10^{-12}}}{\sqrt{1 - (1.56 \times 10^9 / 2.45 \times 10^9)^2}} \\ &= 489 \Omega \quad \dots (1) \end{aligned}$$

[0066]

[Equation 2]

また、導波管内が誘電体である場合の特性インピーダンス  $Z$  は、

$$\begin{aligned} Z &= \frac{\sqrt{4\pi \times 10^{-7} / 2.1 / 8.85 \times 10^{-12}}}{\sqrt{1 - (1.08 \times 10^9 / 2.45 \times 10^9)^2}} \\ &= 289 \Omega \quad \dots (2) \end{aligned}$$

[0067] Characteristic-impedance  $Z$  (an electrical potential difference/current) is lower than the time of the inside of a waveguide being air by inserting a dielectric in a waveguide so that



clearly from a formula 1 and a formula 2. Thereby, when injection power (electrical-potential-difference  $\times$  current) is the same, it can say that it is [ an electrical potential difference ] lower to insert in a dielectric. Since the voltage standing wave of the microwave which spreads the inside of a waveguide is used when the antenna section 15 is formed with the metal conducting bar, the cash-drawer potential of the antenna section 15 falls. Therefore, with the gestalt of this operation, since dielectric 12c is inserted in in the waveguide 12, the potential near the antenna section 15 is low, and when high power is supplied to equipment, the often produced abnormality discharge can be prevented. Moreover, microwave power can be stabilized and supplied to the dielectric wire way 13.

[0068] By the way, the guide wave lengths of microwave differ by the case where they are the case where the inside of a waveguide 12 is air, and a dielectric. The case of the flat waveguide which has width-of-face dimension  $a \times$  height dimension  $b=96\text{mm} \times 27\text{mm}$  which crosses this in the direction of a tube axis is mentioned as an example, and is explained. It can ask for guide wave length  $\lambda_{\text{dag}}$  by the following formulas.

$$\lambda_{\text{dag}} = \lambda_{\text{da}} / \sqrt{1 - (\lambda_{\text{da}}^2 / \lambda_{\text{dac}}^2)}$$

However, vacuum wavelength  $\lambda_{\text{da}} = 3 \times 10^{11} / 2.45 \times 10^9 = 122\text{mm}$  cut-off wavelength  $\lambda_{\text{dac}} = 2a = 192\text{mm}$  [0069] First, when the inside of a waveguide 12 is air, they are  $\lambda_{\text{dag}} = \lambda_{\text{da}} / \sqrt{1 - (122/192)^2}$ .

= When the inside of 158mm and a waveguide 12 is Teflon (trademark)  $\lambda_{\text{dag}} = \lambda_{\text{da}} / \epsilon_{\text{r}} / \sqrt{1 - (\lambda_{\text{da}}^2 / \epsilon_{\text{r}} \lambda_{\text{dac}}^2)}$ ,

$$= 122 / \sqrt{2.1} / \sqrt{1 - (122 / \sqrt{2.1} / 192)^2}$$

= 94mm, however specific-inductive-capacity  $\epsilon_{\text{r}}$  of Teflon It is  $\epsilon_{\text{r}} = 2.1$ .

[0070] Moreover, when Teflon is inserted in using the waveguide for Teflons (width-of-face dimension  $a = a / \sqrt{2.1}$ ) as a flat waveguide  $\lambda_{\text{dag}} = \lambda_{\text{da}} / \epsilon_{\text{r}} / \sqrt{1 - (\lambda_{\text{da}}^2 / \epsilon_{\text{r}} \lambda_{\text{dac}}^2 \times \sqrt{2.1})^2}$ ,

= 109mm or more shows that the guide wave length of the microwave at the time of inserting in Teflon (trademark) in a waveguide 12 becomes shorter than the case where it does not insert in.

[0071] A dielectric is inserted in in gestalt 7. of operation, next a waveguide, and the plasma treatment equipment which formed the slit as the antenna section is explained. Drawing 12 is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 7 of operation of this invention. In the waveguide 12, dielectric 12c like Teflon (trademark) is inserted in. It fills up with dielectric 12c in the direction of a tube axis from the reflective edge 12e side of a waveguide 12 to the predetermined location, and taper section 12a to which the edge by the side of a microwave oscillator 10 made upside thickness thin is formed. It has prepared in order for taper section 12a to make matching section reflection of microwave reduce, and the dimension is  $n/4 \times \lambda_{\text{dag}}$  in the direction of a tube axis. However, an integer,  $n \geq 1$ , and  $\lambda_{\text{dag}}$  of  $n$  are the wavelength in the microwave tube.

[0072] Two or more slits which function as the antenna section are formed in the base of a waveguide 12. the 1- the 5th antenna section 261 and 262, 263, 264, 265 is the mode which penetrates the metal wall on the dielectric wire way 13, has a slit core in the location from which only  $x(1/2) \lambda_{\text{dag}}$ ,  $\lambda_{\text{dag}}$ ,  $x(3/2) \lambda_{\text{dag}}$ ,  $2\lambda_{\text{dag}}$ , and  $(5/2) \lambda_{\text{dag}}$  were separated sequentially from reflective edge 12e, and is prepared in it. And the 3rd antenna section 263 is formed in the core in the top face of the dielectric wire way 13, and the 2nd and 4th antenna sections 262, 264 are formed in the 1st and 5th antenna section 261, 265 lists to the 3rd antenna section 263 at the position of symmetry. The inside of drawing, and distance  $L1$  They are  $= (1/2) \lambda_{\text{dag}}$ , distance  $L2 = \lambda_{\text{dag}}$ , distance  $L3 = (3/2) \lambda_{\text{dag}}$ , distance  $L4 = 2\lambda_{\text{dag}}$ , and distance  $L5 = (5/2) \lambda_{\text{dag}}$ . Other configurations and the procedure of plasma treatment are the same as that of the gestalt 5 of operation mentioned above, and omit the explanation.

[0073] In addition, although the antenna section of the gestalt of this operation is not restricted to the location mentioned above, it is desirable to have prepared in the location which separated only  $x \lambda_{\text{dag}}$  (an integer,  $n \geq 1$ , and  $\lambda_{\text{dag}}$  are the wavelength in the microwave tube for  $n$ ) from reflective edge 12e ( $n/2$ ).

[0074] It is higher for a current for characteristic-impedance  $Z$  in a waveguide to have been low as compared with the case where the dielectric is not inserted in in the waveguide 12, and to

insert in a dielectric by such the charge of dielectric 12c, when injection power (electrical-potential-difference x current) is the same as mentioned above. The electrical-potential-difference value is falling by this in the location of the antinode of the voltage standing wave in a waveguide, and the current value is increasing to coincidence in the location of the antinode of the current standing wave of a waveguide wall surface. Since the current standing wave of the microwave formed in a waveguide wall surface is used when the antenna section is formed to the slit, the electric field which leak and come out of a slit increase. Since each slit is prepared in the location of the antinode of a current standing wave with the gestalt of this operation, as compared with the case where the dielectric is not inserted in in a waveguide, the potential difference produced between the long sides of slit opening becomes high, and can carry out generation maintenance of the high density plasma effectively with the same power.

[0075] In addition, although the case where etching processing is performed to the semiconductor substrate W is mentioned as an example and the gestalten 1-5 of operation mentioned above explain it, it does not restrict to this, and if it is plasma treatment, effectiveness with the same said of the case where ashing processing, CVD processing, etc. are performed can be acquired.

[0076] Moreover, with the gestalten 1-5 of operation mentioned above, although the dielectric wire way and the microwave installation aperture explain the case where it has the shape of a disk type, they may not be restricted to this and may use things, such as a rectangle plate configuration. However, it is desirable to make the configuration (for example, rectangular parallelepiped husks configuration) of a reaction chamber suit.

[0077]

[Effect of the Invention] As mentioned above, in this invention, since it has joined in the direction at which a waveguide and a dielectric wire way are allotted in parallel, and it crosses in the direction of a track together through the antenna section, the field for adjustment of the microwave resulting from a difference of the dimension of each part of both can be omitted, and equipment is miniaturized. Moreover, when the antenna section of the shape of the waveguide which could prevent the abnormality discharge which is easy to produce when a dielectric is inserted in in a waveguide, and high power is supplied, in addition inserted in the dielectric, a dielectric wire way, and a slit to penetrate is prepared, the potential difference between a waveguide and a dielectric wire way becomes large, and can generate the high density plasma efficiently.

[0078] Furthermore, since microwave is introduced from the center section of the dielectric wire way and it is made to spread toward a periphery, it becomes possible to make homogeneity produce the plasma in the reaction chamber of the diameter of macrostomia, and the processing precision of a sample improves. by carrying out adjustable setting of the gap dimension between a dielectric wire way and a microwave installation aperture according to the condition of the plasma in a reaction chamber, ignition of the plasma can be made easy, and homogeneity can be made to generate the plasma after that, and efficient plasma treatment is possible further again -- etc. -- this invention does the outstanding effectiveness so.

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[Translation done.]

## \* NOTICES \*

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- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.\*\*\*\* shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

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DESCRIPTION OF DRAWINGS

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## [Brief Description of the Drawings]

[Drawing 1] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 1 of operation of this invention.

[Drawing 2] It is the cross-sectional view seen from the II-II line of drawing 1 .

[Drawing 3] It is the sectional view having expanded and shown a part for the bond part of a waveguide and a dielectric wire way.

[Drawing 4] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 2 of operation of this invention.

[Drawing 5] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 3 of operation of this invention.

[Drawing 6] It is drawing of longitudinal section showing the structure of other plasma treatment equipments of the gestalt 3 of operation of this invention.

[Drawing 7] It is the graph which shows the field strength distribution in the dielectric wire way by the propagating mode of microwave.

[Drawing 8] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 4 of operation of this invention.

[Drawing 9] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 5 of operation of this invention.

[Drawing 10] It is the cross-sectional view seen from X-X-ray of drawing 9 .

[Drawing 11] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 6 of operation of this invention.

[Drawing 12] It is drawing of longitudinal section showing the structure of the plasma treatment equipment of the gestalt 7 of operation of this invention.

[Drawing 13] It is drawing of longitudinal section showing the structure of conventional plasma treatment equipment.

[Drawing 14] It is the top view of drawing 13 .

## [Description of Notations]

- 1 Reaction Chamber
- 2 Air Gap
- 4 4a Microwave installation aperture
- 7 Sample Base
- 10 Microwave Oscillator
- 11 Microwave Induction Room
- 11a Rise-and-fall section
- 12 Waveguide
- 12e Reflective edge
- 13 13a Dielectric wire way
- 15 Antenna Section
- 15a Conducting bar
- 15b Insulator
- 16 Rise-and-Fall Driving Gear

151,251,261 The 1st antenna section  
152,252,262 The 2nd antenna section  
253,263 The 3rd antenna section  
264 4th Antenna Section  
265 5th Antenna Section

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[Translation done.]